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B. T. GALLOWAY, *Chief of Bureau.*

THE MISTLETOE PEST IN THE SOUTHWEST.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 24, 1909.

Sir: I have the honor to transmit herewith a paper entitled "The Mistletoe Pest in the Southwest," by Prof. William L. Bray, formerly a special agent in the Office of Investigations in Forest Pathology.

The paper embodies the results of several years of investigation of the various phases of the mistletoe pest and an account of the methods of combating it that are known at present. The subject of control of the mistletoe pest is still under investigation in this Bureau. This paper, however, marks the completion of Professor Bray's work on the subject. I recommend that it be published as Bulletin No. 166 of the special series of this Bureau.

Respectfully,

A. F. Woods,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—515.

THE MISTLETOE PEST IN THE SOUTHWEST.

INTRODUCTION.

The name "mistletoe" was long ago applied to the mysterious parasitic European shrub to which, centuries later, Linnæus gave the technical name *Viscum album*, by which name it is at present distinguished from other related species also called mistletoe. These other more or less closely related species have been discovered from time to time in almost all parts of the world—certainly in most of the warm countries—until at the present time a large kinship circle or family of mistletoes is known, embracing more than 600 species. In the course of botanical explorations in the Western Hemisphere numerous representatives of this family were found, and among them one which so closely resembled the original mistletoe that it was given the generic name Viscum, with the specific designation flavescens; indeed, one early botanical explorer, Thomas Walter, called specimens found in the Carolinas *Viscum album*, under the impression that they were identical with the European plant. Later, the pioneer botanist, Nuttall, suggested that the American plant differed from the European one widely enough to deserve separate generic distinction, and so proposed the name *Phoradendron* (tree thief). The name then became *Phoradendron flavescens*. Interestingly enough, the specimen upon which this name was based was from Texas.

In spite of the fact that there are some scores of species of mistletoe in the Americas (including the West Indies), this *Phoradendron flavescens* enjoys the distinction of being *the* American mistletoe, and has been accepted in this country in lieu of the genuine mistletoe of Europe and invested with much of its traditional and historical setting.

DISTRIBUTION AND HARMFUL OCCURRENCE OF MISTLETOE.

The American mistletoe is a leafy, green, parasitic shrub, commonly found growing upon various species of broad-leaved trees throughout the Southern States and extending in more or less modified forms across Texas, southern New Mexico, and Arizona to southern California, and thence northward in the coast region to

Oregon and Washington. Eastward its northern limit is in New Jersey, southern Pennsylvania, southern Ohio, Indiana, Illinois, Missouri, and eastern Oklahoma. Speaking generally, mistletoe is held in rather high regard everywhere because of its inherently interesting mode of life, because of the traditional and historical atmosphere which invests the original mistletoe of Europe, and because of its desirability, for the above and other reasons, as a decorative Christmas shrub. The fact that it is a parasite implies a possible injury to the tree upon which it grows, but, again speaking generally, the injury is regarded as relatively slight and more than offset by the feeling of regard for the parasite. Among people who see it rarely, and, especially among those living in northern cities who purchase small sprigs or bunches of it at a good price for Christmas decoration, the idea of mistletoe being a harmful parasite upon trees is quite lost sight of. Nevertheless, there are localities in which mistletoe becomes so abundant upon trees and so harmful to them as to make the control of it or its extermination a serious practical question.

This is notably the case in parts of Texas. Between the ninety-sixth and ninety-seventh meridians in Texas is a belt of country in which mistletoe is a serious parasite in many localities. The area most harmfully infected would be comprised in a circle of 100 miles, more or less, in radius, having its center at Austin. The north-south extension of this area is really greater than its east-west dimensions, for to the eastward one passes presently into the more humid and more heavily timbered country, and westward the available hosts for the parasite become fewer.

The climatic conditions of this area have a more or less direct bearing upon the question. Between the ninety-sixth and ninety-seventh meridians in Texas and Oklahoma lies a zone of transition from the humid climate of the Gulf States to the arid climate of the Southwest. The heavy forest growth of the South does not enter this belt, except as it follows the moist soils of river and creek bottoms, and even in these favorable situations the luxuriant growth becomes checked by the decreasing rainfall and drier atmosphere. Upland tree growth is stunted; the trees occur more sparsely, are broader of crown, less tall, and more frequently of imperfect growth. The trees bear evidence of a struggle against unfavorable conditions. In this region it becomes a difficult matter to secure umbrageous trees for shading and beautifying streets and parks and private grounds. Not many native species are suitable for these purposes. Very little has been done toward the solution of the whole question of selection, planting, and care of shade trees.

In spite of the less inviting conditions for forest growth, mistletoe appears to flourish better in this belt than elsewhere; at least, it is

relatively more abundant than it is eastward. It is a curious fact, whose explanation is not very obvious, that mistletoe is more varied in form and relatively more abundant in the arid districts of the Southwest (e. g., portions of New Mexico and southern California) than it is in the Gulf States east of the ninety-sixth meridian. It is not that the growth of mistletoe as a shrub is more vigorous than in the eastern belt; as a matter of fact, in the more humid climate it makes a most luxuriant and symmetrical growth, but fewer of the trees relatively are infected and these evidently in more restricted localities.[a] In river or creek bottoms or in swamps one sees the taller trees with bunches of mistletoe far up on the remote branches. In middle Texas, on the contrary, mistletoe is by no means confined to bottom-land trees, but it infests those of upland prairies also. Stunted native growths and transplanted trees are especially apt to be infected, and not merely by isolated bunches of mistletoe on remote branches, but throughout the tree on old as well as young branches, and not infrequently upon the main trunk itself, so that the whole tree is infected, weakened and disfigured, and finally killed. (Pl. I, fig. 1.) Thus it comes about that just in the region where trees in perfection are especially difficult to find they are more than elsewhere subject to harmful infection by this parasite. The explanation may be suggested that mistletoe, like a good many other plants of arid situations, requires much sunlight for its best growth and especially for the development of flowers, and thereby of numerous and vigorous seeds, and is at a disadvantage in competing with the heavy shade-casting foliage of forests in humid climates. The necessity for light might explain why in bottom-land forests of the East mistletoe is confined to the highest branches of the tallest trees (as shown by observations made in the case of bottom-land timber in parts of Arkansas, southeastern Oklahoma, and northeastern Texas), and how with increasing intensity of sunlight and the more meager foliage and open stand of trees incident to the drier climate of the Southwest mistletoe is enabled to spread over the entire tree.

That more arid environmental conditions have acted in the nature of a stimulus to mistletoe in its growth and reproduction may be alleged from the fact that in the arid Southwest there is much more variation in the habit of the plant than there is in the Atlantic and Gulf forest regions. Thus between middle Texas and southern California there are several distinct types or varieties of *Phoradendron flavescens* (*macrophyllum*, *villosum*, *orbiculatum*, and *pubescens*), besides several more distinct species, notably *Phoradendron californi-*

[a] Exceptions to this statement are not unusual. Thus, at Houston, Tex., at various points in Louisiana, and also in some localities in Mississippi and Tennessee, mistletoe has been reported as harmfully abundant in isolated trees or clumps of trees in dooryards and parks.

cum, which infests many species of desert trees and shrubs, and *Phoradendron bolleanum* and *P. juniperum*, which last two are especially noteworthy as being parasitic upon coniferous trees, especially desert junipers.

BIOLOGY AND LIFE HISTORY.

A brief account of the life history and of the habits of nutrition of mistletoe will assist in making clear the reason for its harmfulness to trees. The plant is a parasite. It fastens itself upon its host, the tree, penetrates its tissues, and draws nourishment from it, deforming it and sapping its vitality. Yet the mistletoe is a green, leafy plant; that is, it possesses the pigment chlorophyll, which gives the green color to normal vegetation. Some of the tropical species of mistletoe bear leaves as large as those of an American elm. The presence of green leaves indicates that the mistletoe has the power, which independent green plants everywhere possess, of constructing organic foodstuffs, such as starch, out of inorganic compounds (carbon dioxid and water), utilizing sunlight as the source of energy in the process. It is therefore only partly a parasite so far as dependence upon a host for food is concerned, but apparently none the less harmful on that account. It secures from its host apparently only what the normal, shrubby plant derives from the soil, namely, water and certain necessary mineral constituents. Imagine a grapevine or trumpet creeper, while retaining its foliage, to sever connection with the soil and to thrust root-like outgrowths into the body of the tree to which it clings, in order to absorb from the tree what before it absorbed from the soil. This would represent the relation which mistletoe sustains to its host.

In this connection it is instructive to observe that the mistletoe family, viewed as a whole, shows a progressive development of parasitism. Thus at one end of the series stands the Australian genus Nuytsia, whose single species is a nonparasitic tree. At the opposite extreme is the degenerate, absolute parasite *Phrygilanthus aphyllus*, parasitic upon a cactus of the genus Cereus in Chile. This plant is said to possess neither cotyledons nor foliage leaves, nor does it develop the vigorous shrubby habit characteristic of mistletoes generally. The more familiar mistletoes are sometimes called "half parasites," but they also show great variation in habit from the very broad-leaved forms above mentioned down to those which are yellow-green and quite leafless; e. g., *Phoradendron juniperum* and *Arceuthobium pusillum*, the latter of which barely emerges from its host.

In the general sequence of events the life history of mistletoe is just like that of any flowering woody plant; for example, the hackberry, upon which it preys. It bears flowers; in due time the berries follow, each with its inclosed seed; the berries are deposited by birds

or beaten down by rains upon the branches, where under favorable conditions the seeds germinate, and if the seedling becomes established upon the branch it grows again to the age of producing flowers and seed, and so on from generation to generation. Of course the mistletoe seed is more limited than the hackberry in its choice of a substratum upon which to grow, since the only situation in which it has any prospect of developing a plant is upon some part of a living tree.

DEVELOPMENT OF FLOWERS AND FRUIT.

The flowers of the American mistletoe are minute and inconspicuous, although in some tropical mistletoes they are relatively large and showy. The flowering season in Texas falls usually in December, which is approximately the date of flowering for the species throughout its range. The plant is dicœcious; that is, any one individual is wholly male or wholly female. Manifestly some plants never produce berries. This separateness of pollen-producing and ovule-producing plants makes it a matter of importance whether female and male plants grow in close proximity and whether there are any special means by which pollination is effected. Several of the conspicuous-flowered tropical mistletoes are regularly pollinated by insects. It is claimed also that the European mistletoe (*Viscum album*) is pollinated by insects, but so far as has been determined the American mistletoe apparently depends upon the wind to carry its pollen.

After the flowering period and pollination, the development of seed and berry goes forward very slowly. With the approach of the following winter the berry begins to enlarge and by December the seeds are ripe and the berries pulpy and white. Thus it happens that the flowering season of this year coincides with the ripening of fruits begun a year ago.

DISTRIBUTION OF SEED BY BIRDS AND OTHERWISE.

The seed when ripe is inclosed in a clear, sticky pulp covered by a tough, semitransparent skin, the whole constituting the mistletoe berry.[a] This pulp appears to be in some degree an object of food to certain birds, notably to mocking birds, cedar birds or waxwings, and to robins in Texas,[b] and the seeds are distributed in considerable

[a] In the case of the European mistletoe the sticky pulp of the berry is utilized in the preparation of bird lime.

[b] Doubtless most berry-eating birds feed more or less upon mistletoe berries, according to the abundance or scarcity of other, choicer kinds. Thus in Bulletin No. 120 of the University of Texas on the American mistletoe, page 7, Mr. York reports that sparrows and cardinals are the principal birds, next to the mocking birds, which feed upon mistletoe berries.

numbers by these birds either in their excrement or by being wiped from the beak against a branch in the birds' efforts to remove the adhesive pulp. In either case the pulp still remaining about the seed causes it to stick to the branch and by drying to become firmly pasted there. It is the conclusion of most observers that the mocking bird is the chief distributer of mistletoe seed, but perhaps the cedar birds actually distribute more, for in March and April these birds appear in flocks of hundreds in search of berry mast—especially hackberries—and during the brief visits of a few days or a week or two all the berry-laden trees are visited repeatedly until the berries are gone. During these flights, mistletoe berries are also eaten, though probably not much noticed until the hackberry crop is exhausted. Robins also are reported to be common distributers of mistletoe seed. In the vicinity of Austin large flocks of robins spend the winter, or part of it, in the cedar brakes, where they feed largely on cedar mast; but at times they appear in numbers about farmyards and in towns, feeding upon hackberries, and during these visits also upon mistletoe berries.

Mistletoe is, however, not wholly dependent upon birds for the distribution of its seeds, for as the spring advances and the berries grow softer they fall away easily, becoming crushed and adhering to the branch below. Especially are they beaten off in heavy downpours of rain and washed against the branches, where they are left adhering in favorable situations for germination. The character of infection of certain cedar elm trees illustrates very plainly this method of infection. Pendent branches become laden with bunches of mistletoe from base to tip, showing how the seeds were washed down the branch during a heavy rainfall.

STRUCTURE AND VITALITY OF THE SEED.

Of course, mistletoe seeds become planted in the ways just described in all sorts of places and in favorable weather are induced to germinate in almost any situation—upon branches, upon the main trunk, upon leaves, dead twigs, fences, and even upon mistletoe itself—but the only situation in which there is any prospect of this germination resulting in the establishment of a mistletoe plant is, as previously stated, upon the living branch or trunk of a tree, and only then where the bark is thin or cleft, or otherwise in a condition to permit the penetration of the root axis or sinker of the seedling. In any event, the bark or epidermis of a tree would seem to be barren soil, since it dries so quickly. This is particularly true in central Texas and westward, where the atmosphere is habitually dry. The seeds have need to be strongly drought resistant, and this quality they seem to possess in a marked degree.

They begin to be distributed upon branches in December and January, but favorable conditions for germination are not likely to occur before March, and perhaps not before April or May, depending upon the temperature, and when this is sufficiently high upon the appearance of a period of rainy, humid weather. Whether the seeds placed upon branches in midwinter remain capable of germination as late as April or May is not known, but of course many berries remain to be distributed as late as May. If it be true that birds eat mistletoe berries only when other choicer kinds are no longer available, then the chief season of distribution would about coincide with the more favorable conditions for germination.

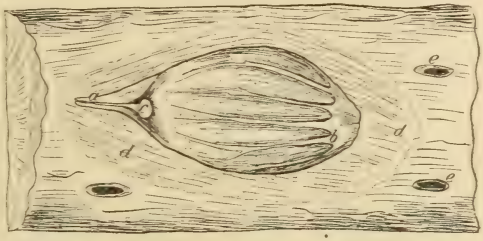

FIG. 1.—A seed of mistletoe pasted on a branch by berry pulp and ready to germinate: *a*, Beak of seed coat; *b*, fibrous coat of seed; *c*, root tip of embryo; *d*, *d*, berry pulp; *e*, *e*, lenticels on branch. All very much enlarged.

The pulpy covering in which seeds are embedded upon a branch is a protection to them against extreme drying out and doubtless useful also in absorbing water before germination, thus allowing the seed to lie in a moist, slimy matrix. (See fig. 1.) The seed structure proper is also adapted to the arid conditions upon a branch. The seed is invested in a fibrous coat (endocarp) quite unlike the customary hard shell of berry seeds, which is peculiarly active in absorbing water and transmitting it to the living parts within. The peculiar thickening of the walls of the cells in this fibrous coat suggests the water-absorbing tracheid cells of sphagnum moss and of the velamen in the air roots of certain orchids, both of which types are noteworthy because of their water-absorbing properties.

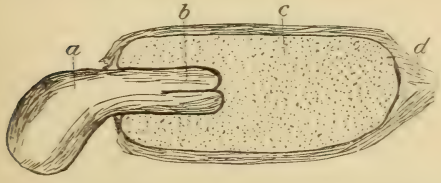

FIG. 2.—Sectional view of a germinating mistletoe seed: *a*, Embryo, showing knob-like enlargement of root end; *b*, cotyledons of embryo; *c*, endosperm or food supply; *d*, fibrous seed coat.

Within the fibrous coat lies a body of food material or endosperm in which the minute embryo lies embedded, except for its slightly protruding root tip (fig. 2). Both embryo and endosperm retain chlorophyll pigment throughout the dormant period, but previous to germination the green color becomes intensified and the presence of a gas (oxygen?) in the interspaces shows that the seed is already a carbon-assimilating body, able to proceed with its development within the moment of arrival of favorable conditions or of lying dormant and uninjured with the return of arid conditions. It

appears capable of repeating this behavior of alternate activity and dormancy throughout the germination period and until the seedling is fully established, and therefore less influenced by sudden fluctuations of moisture and dryness. In short, the seed in its germination phase is a well-adapted drought plant or xerophyte.

GERMINATION AND ESTABLISHMENT OF THE SEEDLING.

The first apparent movement in germination consists in the elongation of the axis (hypocotyl) of the embryo, whereby the root tip is thrust beyond the beak of the seed jacket, thus becoming directly exposed to the air and sunlight. Upon becoming exposed the axis bends so as to bring the blunt end of it into contact with the underlying branch. This prompt bending in its growth appears to indicate a sensitiveness of the tip toward the branch, but it has been shown that it is on account of its sensitiveness to light that the axis bends, and the bending has for its object the avoidance of too intense illumination. This, however, results in bringing the root tip of the embryo against the branch. The root end of the embryo is blunt or even knob-shaped while still within the seed jacket, and as it emerges and turns toward the branch the end further enlarges until it becomes prominently knob-formed even before it comes into contact with any underlying object (fig. 2). When, however, it touches the branch, the knob becomes broader and is flattened on the contact side, as when a plastic object is pressed firmly against a hard surface. Thus it behaves like an adhering disk or sucker, such as one observes in the Boston ivy, where the tips of the clinging tendrils flatten against the wall. At the center of the flattened disk the cells continue to push forward, with the result that a point of tissue, the primary sinker, bores its way, or, perhaps more accurately, dissolves its way, into the tissues of the branch (fig. 3), for the cells of this puncturing point are able to secrete a substance (enzyme) capable of dissolving the walls of cells lying in its path. Thus it really dissolves and absorbs the tissue of the host. This primary sinker pushes downward through the soft bark zone (cortex, phloem, and cambium) until it reaches the younger wood cells. Meanwhile an axial strand of cells in the primary sinker becomes differentiated into water-transporting tracheids,

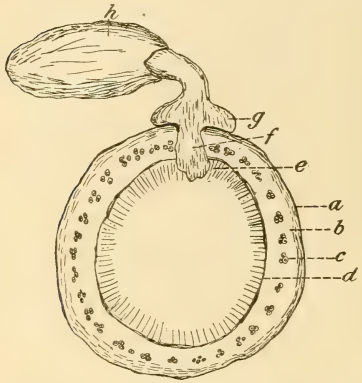

FIG. 3.—Diagram showing the method of penetrating a branch by a mistletoe seedling: *a*, Corky covering of branch; *b*, cortex zone; *c*, bast fibers; *d*, cambium or growth ring; *e*, wood zone; *f*, sinker of mistletoe penetrating to wood zone; *g*, disk; *h*, body of mistletoe seed.

of which those formed in the wood zone of the host become applied to the water-carrying cells of the host, thus establishing an efficient means of conducting water and mineral nutrients from the host into the parasite. The mistletoe seedling is now virtually a tiny bud graft (fig. 3).

Having thus established its connection with the source of some of its food supply, the upper end of the hypocotyl with the minute cotyledons gradually withdraws from the inclosing and partly digested endosperm, and becoming erect the cotyledons slowly expand as the first pair of green leaves. Perhaps this is as far as development goes during the first season. In some species of mistletoe the cotyledons remain covered by the seed jacket and endosperm (if there is any) during all of the first season. Apparently the progress of development at this period depends upon weather conditions. In a dry climate these are apt to be such as to interrupt repeatedly the progress of germination and of becoming established. Existence becomes largely a question of endurance during this period, and it is probable that in a season of unusual warmth and humidity the seedling progresses in its development farther than merely to expand the cotyledons; whereas, in an unfavorable season, if the seedling survives at all it may approach the winter with germination, in the popular sense, still incomplete. This seems to be a reasonable interpretation of facts and conditions thus far observed in the field, and it points with renewed emphasis to the peculiarly resistant qualities of the mistletoe at this period of its existence. In spite of these qualities, however, the great majority of mistletoe seedlings perish, or the seeds never germinate at all in the face of such extreme arid conditions as frequently prevail.

It should be noted that the mistletoe in establishing itself as previously described, with its primary sinker in contact with the wood cells, has the problem of adjusting itself to the season's growth in thickness. This it does by maintaining a zone of embryonic tissue in the sinker corresponding to the cambium zone of the host.

Some time after the seedling has established itself as described, probably not until the second season's growth, there arise from the primary sinker in the zone of soft bark, or cortex, lateral outgrowths called cortical roots, or cortical haustoria, which spread along and around the host stem in this cortex zone, extending farther and farther from the original point of penetration (fig. 4). At intervals from the side of the cortical roots nearest the wood zone more sinkers arise and penetrate along the line of least resistance (medullary rays) into the wood, where they develop a connection with the water-carrying vessels as the primary sinker did. These cortical roots persist and increase in thickness; indeed, it appears to be the thickening of these at their junction with the parent axis which gives the enlarging

mistletoe bush its strongly buttressed attachment to the branch (fig. 4). The presence of these persistent cortical roots interrupts the formation of host tissue exterior to them, and thus they come to lie more or less exposed along the surface of the branch. At these exposed places (possibly also from the younger cortical roots still within the cortex zone) adventitious buds are developed which may give rise to new mistletoe shoots. (See figs. 5 and 6.) They do this in considerable numbers if from any cause the original mistletoe plant is injured, or especially if it be broken off, as is most frequently done when the effort is made to rid a tree of the parasite. In this way the cortical roots are stimulated to further growth and to giving rise to repeated crops of mistletoe shoots. Scraping off the old plants stimulates the development of more adventitious buds and thus tends to enlarge the area of infection.

FIG. 4.—Sectional view, partly diagrammatic, of a branch infected with mistletoe, showing the relation between parasite and host: *a*, Branch of host tree; *b*, mistletoe; *c*, primary sinker; *d*, sinker from cortical root *e*; *f*, cortex or soft bark; *g*, cambium or growth ring; *h*, wood of branch. The starving and dwarfing of the branch beyond the mistletoe is shown at *i*.

It has been observed that in some trees, or at least in some situations on the branch, there is no considerable spread of cortical roots and no development of shoots from adventitious buds. Thus, in the case of the water oak one may find huge bushes of mistletoe a yard in diameter on branches eight or ten years old with not a single indication of the spread of the infection along the branch. This may be observed also in the mesquite and doubtless in any other tree where the primary mistletoe plant started on a very young branch and has developed unharmed. (See fig. 5.) In the course of time, however, the original plant is destroyed by some agency or other, but the cortical roots persist and thenceforth develop secondary shoots from adventitious buds. In this way may be explained the characteristic occurrence of mistletoe on old branches and even on trunks, as shown not

infrequently on mesquite and very commonly on hackberry. The cortical haustoria have persisted for years, in many cases producing an unsightly deformity of the branch or trunk (fig. 7). There is an obvious similarity between this behavior of mistletoe and that of certain noxious weeds, such as Johnson grass, where from an original plant underground rootstocks spread in all directions, sending down more roots into the soil and sending up plant after plant into the air until a wide area is beset by it; also in the further respect that merely cutting off the tops only serves to stimulate the underground parts to greater activity in spreading and breaking out in new places.

FIG. 5.—Mistletoe on a branch of a cedar elm tree, showing the starved end of the branch and how mistletoe comes to be terminal on a branch.

RATE OF GROWTH.

During the period in which the parasite is becoming established the rate of development, as already shown, is extremely slow. During the whole of the first season the mistletoe plant may not grow more than a quarter or half inch in length. After becoming thoroughly established, however, growth is relatively rapid, depending, as does the host also, upon the character of the season. The shoots from adventitious buds have been observed to grow to the length of 4 to 6 inches in a single season following the spring pruning of the previously developed crop of shoots. In the case of water oaks growing in wet bottom-land soil, bunches of mistletoe have been observed to develop in six to eight years into a shrub having a

spread of nearly 3 feet and to be more than an inch in diameter just above the buttressed point of attachment to the slender branch of the host (Pl. II, fig. 1). The rate of growth varies with the host, being much slower in the cases of the mesquite and the osage orange. The location of the host with respect to moist or dry soils naturally also affects the rate of growth of the parasite.

LONGEVITY.

The parts of mistletoe embedded in the tissues of its host appear to have no fixed limit to continued existence except the death of its host. Specific data in this connection are not at hand for the

FIG. 6.—A branch of an Osage orange tree infected with mistletoe, showing deformity and multiplication of branches at the point of infection.

American mistletoe, but in the case of European mistletoe Tubeuf states that often sinkers are found extending through sixty to seventy annual rings of growth. There are many cases in Texas where mistletoe has been repeatedly broken from large branches during the past twenty or twenty-five years. In cases where the trunk of the mesquite and the hackberry are notably deformed it is probable that the infection is nearly as old as the host.

With regard to the aerial part it would appear that any single bush would scarcely survive more than eight or ten years, chiefly because of the likelihood of its being broken off by storms, or being

killed by freezing, or otherwise being mechanically destroyed. It is maintained that in extreme cold weather mistletoe has been largely killed out over large areas; for example, in the unprecedented cold wave of February, 1900. Its own bulkiness and brittleness would seem to operate toward the self-destruction of the mistletoe bush. In the case of infection upon the mesquite, spoken of elsewhere, the parasite so injures the branch upon which it sits as to kill the branch and thereby destroy itself. Usually, however, accident to the aerial part of the parasite merely results in stimulating the development of adventitious buds—and thereby in multiplying the number of mistletoe shoots upon a gradually widening area of infection.

EFFECT UPON THE HOST.

Perhaps in the majority of cases the original point of infection is upon a small, remote branch. The habit of the mistletoe is of course to draw sustenance from the branch and in increasing quantity as the parasite increases in size. The immediate result is to starve that portion of the branch lying beyond the point of infection, and while this part may persist for some years alive without noticeable growth, in the end it dies, and the mistletoe thus comes to occupy the end of the branch. (See fig. 5.) This habit is particularly well shown in the water oak, where very large clusters 2 to 3 feet in diameter swing from the end of a long slender branch not more than an inch in diameter next the swollen point of junction of the host and parasite (Pl. II, fig. 1). At the point of attachment also the branch is stimulated to excessive growth, which gives rise to deformities of varying shapes on different host species. In the water oak just mentioned both branch and mistletoe are enlarged like a clumsy piece of welding. Frequently, as in the Osage orange, the branch is stimulated to an excessive formation of shoots, forming a sort of witches' broom. (See fig. 6 and Pl. II, fig. 2.) Large branches, and not infrequently the main trunks of trees, may be greatly deformed by the mistletoe. This happens where infection occurred when the tree was young and has persisted to misshape all

FIG. 7.—The trunk of a mesquite tree at Waco, Tex., deformed by long-standing mistletoe infection.

its subsequent growth. (See fig. 7.) On the other hand, very many trees are infected for years without showing any noteworthy deformity, and, as a matter of fact, this item is not one of serious economic importance.

Mistletoe not only causes mechanical injury, but it saps the vitality of the branch and when sufficiently abundant often the whole tree; and in the case of the hackberry, especially, often results in the death of the entire tree. About Austin considerable numbers of hackberry trees have been and are being destroyed in this way. At Bryan, Tex., this is true of water oaks. It has been supposed that perhaps the mistletoe merely supplants the end of the branch which was starved by its presence, and that while it receives what the branch would otherwise receive, it in turn contributes to the tree by its assimilating activity what the displaced branch would have done. This seems never to be the case at any time, and it is certain that when the majority of branches become so supplanted by the mistletoe, the tree dies, showing the parasite to be always a drain upon its host. One of the curious results of infection has been often observed, especially in the Uvalde region, where bunches of mistletoe on remote branches of the mesquite, becoming large, so injure the branch that it decays beneath the mistletoe, which thus itself is starved and killed and presently falls away, leaving the branch free from infection. This is probably due to decay induced by the starving of the branch beyond the original point of infection.

THE POINT OF ATTACK.

In the process of establishing itself upon the host, the critical point for the mistletoe seedling is to penetrate the covering of the branch so as to reach the food-supplying cells of the cortex and wood. The sinker can exert pressure and is doubtless able to force an entrance through fissures or through natural openings, such as lenticels, and between bud scales, as shown by Cannon.[a]

The growing tip of the sinker has been shown to secrete an enzyme capable of dissolving the walls of certain cells lying in its path. Whether heavily cutinized walls or the walls of dead cork cells can be dissolved by this secretion has not been fully determined. Cork and bark certainly offer much more resistance to the forward growth of the sinker than cellulose walls do, and it is quite unlikely that a heavy layer of these could ever be penetrated by a mistletoe sinker. When infection begins on the old parts of a tree it must be at some fissure or thin place in the bark. Naturally the younger branches, and especially twigs of last season's growth, present the most vulnerable points of attack, and as therefore would be expected, infection

[a] Cannon, W. A. Observations on the Germination of Phoradendron villosum and P. californicum. Bulletin, Torrey Botanical Club, vol. 31, pp. 435–443. 1904.

begins in the majority of cases on the remote young branches, where the protective covering is thinner and the lenticels (breathing pores) still numerous. Here also the buds offer a point of attack. Cannon states that in the case of a mesquite branch he has seen as many as a half dozen successive buds bearing mistletoe. The hypocotyl of the seedling pushes its way between bud scales to the more easily penetrated tissue at their base. Cannon also holds that even on the youngest branches the penetration of a sinker is conditioned upon its finding a lenticel or inserting itself between bud scales; but in view of the abundance and varying aspects of infection it seems necessary to ascribe a more active rôle to the sinker than that of mechanically pushing its way through openings and crevices, and that a less haphazard mode of infection prevails. However, no actual proof is at hand that the sinker can secrete an enzyme that will dissolve cutinized or cork cell walls.

The location of the point of infection upon a tree appears also to have some relation to the perching habits of the birds which eat the berries. This idea is held notably in the case of mocking birds. Large areas of mesquite-covered country to the westward of San Antonio show a predominance of cases where a single plant of mistletoe occupies the most conspicuous spot upon the tree, namely, near the apex of the farthest spreading top branch. This appears to coincide with the choice of perching places by the bird in its flight from tree to tree. The habits of cedar birds in their repeated short flights and perching during their spring visits in search of berry mast are also such as to afford the largest likelihood of mistletoe seed being deposited on the youngest branches.

TREES MOST SUSCEPTIBLE TO MISTLETOE INFECTION.

It is a question whether any tree is wholly immune to attacks from mistletoe. Certainly there is reason to believe that mistletoe could be induced to grow upon any living woody plant. But from the actual status of infection in any community where mistletoe grows there are some trees which are practically immune. One of the curious things about the matter is the prevalence of infection upon different species in different localities. Thus, in the vicinity of Austin, the hackberry and the cedar elm are the trees most frequently and heavily infected. The sycamore, though common in central Texas, both native and cultivated, has not been reported to have mistletoe in any case; whereas in the river bottoms of Arkansas and southeastern Oklahoma it is one of the most commonly infected trees. Broad-leaved elms are practically immune in the Austin region, but at Muskogee, Okla., and northward such elms are as thoroughly beset with mistletoe as the cedar elm is at Austin. At San Antonio

and southwestward the mesquite is the chief mistletoe host. At Bryan, which lies farther within the humid belt, the water oak is the most infected species. At Marble Falls, about equally distant but westward from Austin, the live oak and mesquite are reported as the main hosts. So in the osage orange belt of northeastern Texas—notably from Greenville to Paris—that species (*Toxylon pomiferum*) is more infected than others. In the vicinity of Calvert, Tex., the blackjack oak (*Quercus marilandica*) is abundantly infected, but other species not notably so. In reality, the species most infected in all these instances are either the most abundant or else the most prominent in certain situations; for example, along water courses or about farmyards and in towns. Even so, it is not clear why, for instance, the blackjack oak, which is the prevailing host in certain districts, should be comparatively immune in another district where mistletoe is even more common. Extending the range of observation, it is found that the dominant host for *Phoradendron flavescens* and its different forms varies with the geographical location, as follows: In the South, the water oak and other red or black oaks of wet soils, gums, elms, and sycamores; in the Santa Clara Valley, California, especially on deciduous oaks (the prevailing form here being *Phoradendron flavescens villosum*); in southern California *Phoradendron flavescens macrophyllum* on the poplar, willow, ash, and others; at Tucson, Ariz., *Phoradendron flavescens macrophyllum* on the poplar (cottonwood), ash, and black locust, and *Phoradendron flavescens villosum* on oaks and the hackberry.

LIST OF HOSTS OF THE MISTLETOE IN TEXAS.

Pecan (*Hicoria pecan* (Marsh.) Britton).
Hickory (*Hicoria* species). (At Columbus, Tex.)
Post oak (*Quercus minor* (Marsh.) Sargent).
Bur oak (*Quercus macrocarpa* Michx.).
Texan oak (*Quercus texana* Buckl.).
Water oak (*Quercus nigra* L.).
Willow oak (*Quercus phellos* L.).
Blackjack (*Quercus marilandica* Muench.).
Live oak (*Quercus virginiana* Mill.): (Marble Falls and Comanche, Tex.; not noted at Austin).
Cedar elm (*Ulmus crassifolia* Nutt.).
White elm or American elm (*Ulmus americana* L.).
Hackberry or Sugarberry (*Celtis mississippiensis* Bosc., and varieties).
Osage orange (*Toxylon pomiferum* Raf.).
Paper mulberry (*Papyrus papyrifera* (L.) Kuntze).
Sassafras (*Sassafras sassafras* (L.) Karsten).
Sweet gum (*Liquidambar styraciflua* L.).
Apple (cultivated varieties).
Pear (cultivated varieties).
Cherry (*Prunus* species, wild).

Thorn (*Crataegus* species).
Roemer's acacia (*Acacia roemeriana* Scheele).
Mesquite (*Prosopsis juliflora glandulosa* (Torr.) Sargent).
Water locust (*Gleditsia aquatica* Marsh.).
Honey locust (*Gleditsia triacanthos* L.).
Prickly ash (*Xanthoxylum clava-herculis* L.).
China (*Melia azedarach* L.).
Wild China (*Sapindus marginatus* Willd.).
Black gum (*Nyssa sylvatica* Marsh.).
Persimmon (*Diospyros virginiana* L.).
Water ash (*Fraxinus caroliniana* Miller).
Berlandier ash (*Fraxinus berlandieriana* A. de C.).

To this list must be added the interesting case of a climbing vine (*Tecoma radicans* (L.) Juss.) as a host plant observed at Bryan, Tex. No doubt this list might be very much extended by a careful survey throughout the State.

FREEDOM OF INTERCHANGE OF HOSTS.

The question arises as to whether parasitism in the mistletoe is in any considerable degree exclusive, i. e., whether by continued growth on a given host species it becomes less capable of infecting a different species. A survey of the field outside of the *Phoradendron flavescens* circle shows that this sort of thing is possible, at least within certain limits. Thus there is a group of species brought together under the generic name Arceuthobium, all of them being parasitic exclusively upon coniferous trees, and some of them upon one species exclusively. More to the point is the case of the European mistletoe (*Viscum album*) and its circle of related forms. Tubeuf[a] distinguishes three forms: (1) That infecting broad-leaved trees, Laubholz mistel; (2) one which infects fir trees (*Abies pectinata* and *A. cephalonica*), Tannen mistel; and (3) the form parasitic on pines (*Pinus sylvestris* and *P. laricio*), Föhren mistel. Tubeuf maintains that none of these three forms is capable of infecting hosts of the others, and has sustained his position by abundant observations in the forest and by inoculation experiments.

It should be noted here that in the case just cited the form which is parasitic upon broad-leaved trees has numerous hosts—twenty-two host species are listed for a single park forest—and that a good deal of freedom of interchange among hosts is possible. It seems likely, therefore, that the central Texas form of mistletoe may be more or less easily established upon all of the hosts (at least in any given district) by seed carried from the mistletoe growing upon any one of

[a] C. Tubeuf. Die Mistel (Viscum album) Pflanzenpathologische Wandtafeln no. 1 (text), 1906, and more recently in Naturwissenschaftliche Zeitschrift für Land und Forstwirtschaft, no. 5, vol. 7, 1907.

them, and that the immunity which some trees seem to have is due to the mechanical hindrance exercised by the bark or cork, or the simple epidermis, to penetration by the primary sinker, or possibly to the density of shade, as in the case of the China tree (*Melia azedarach*).[b] This relative immunity of species becomes, however, a matter of practical importance as indicating one of the qualities (resistance to mistletoe) that will influence the choice of trees for planting for shade or wind-break or ornament.

Further, it should be noted that the mistletoe varies considerably in habit on different hosts, and especially where the hosts occupy notably different situations as to soil and climate, being in this respect plastic, like the majority of plants capable of existing in widely different soil and climatic conditions. Probably the qualities acquired in any given situation are not such as to forbid a gradual or even ready tolerance for other conditions.

LOCATION OF INFECTED TREES.

Speaking generally, mistletoe-infected trees are those which occupy moist soils, namely, in river bottoms and along creeks and ravines leading to the uplands. In the South generally, certain swamp-inhabiting trees (gums and water oaks) are notably mistletoe hosts. There is no doubt a reason for this in the more or less constant demand which the mistletoe makes on its host for water. In the central Texas mistletoe belt this preference of mistletoe for trees of moist situations is obvious, but it is by no means limited to trees of such locations. Quite on the contrary, the most noteworthy and destructive instances of infection are on isolated trees or clumps of trees in dooryards or parks and along streets and highways. There is a notable preference for isolated trees. Even in timbered bottom lands the heavily infected trees are those which stand out conspicuously in or about a field or clearing. (Pl. I, figs. 1 and 2; Pl. II, fig. 1.) In close stands of timber the average tree seems much less likely to be infected than the same species in the open. Those which are infected in heavy stands are the trees which overtop their neighbors. Perhaps the need of mistletoe for abundant sunlight explains in part its absence in close forests and the predominance of it in exposed trees. This fact is of the greatest consequence in the present consideration, for while the loss to forest trees in a close stand is negligible, the concentrated attack of mistletoe on isolated trees is a blow on a vital spot, for the maintenance of adequate shade trees is a difficult matter, quite apart from the rôle played by mistletoe.

[b] One correspondent states that mistletoe has been observed to grow upon China trees in southern Texas.

A further item of significance in this connection relates to the extension of mistletoe-infected areas. There exist quite obviously local centers of infection. These are most easily seen in cases where a large area is occupied by an open stand of mainly one species, such as the mesquite at San Antonio and the blackjack oak at Calvert. In traversing such timber lands one notes here an area of some square rods or acres in which almost every tree is infected, followed by a long stretch of timber land practically free from mistletoe.

METHODS OF COMBATING THE MISTLETOE.

An understanding of the habits of mistletoe, especially with respect to the mode of spreading the infection, will suggest that the surest way to prevent further spread of infection to new hosts would be to prevent any berries from ripening. This would imply, of course, the virtual extinction of mistletoe from any given community, and it may be questioned whether in spite of its harmfulness such an extreme measure is desired. As stated in the beginning, mistletoe has in many cases, if not generally, a traditional hold upon the regard of people which goes far toward condoning its harmfulness. It is reported that a certain prominent citizen in improving his residence property caused the branches to be pruned from one of his trees and mistletoe to be substituted therefor. (By what means and with what success is not stated.) Possibly one of the chief causes of the present conditions lies in the fact that in tolerating the growth because of its biological interest and because of its traditional setting the parasite has insidiously multiplied upon trees until it has become positively a pest. Those who have tried ineffectually for a decade or more to rid valuable shade trees of mistletoe will doubtless be ready to waive considerations of sentiment and tradition in favor of a radical movement looking to the extermination of the parasite.

The immediate problem is to deal with trees which are already infected. Here, again, a knowledge of the habits of mistletoe will show that where the infection is upon small branches careful pruning of these a few inches below the point where the parasite is attached to the branch will effectually get rid of it. The chief difficulty in this case is simply that of getting up high enough in the tree to do the pruning properly. This difficulty would be materially lessened by employing the common device in which pruning shears are attached to the end of a pole. The shears are operated by means of a heavy cord attached to the free lever arm. No indiscriminate lopping of branches or breaking them off with ragged fractures should be tolerated. Where, however, the infection is in the larger branches or on the trunk in which the cortical roots of mistletoe have

ramified for years, and where innumerable sinkers penetrate the wood, the task of riddance is altogether more formidable. The embedded parts of the parasite are just as tenacious of life as are the rootstocks of Johnson grass, so that scraping or breaking off the external growth results, as in Johnson grass, in the sprouting up of more plants. Mistletoe, however, can be kept well under control by cutting off these successive crops of sprouts, and where this is done every year or two the trees are kept more sightly and the damaging effects of the mistletoe reduced to a negligible quantity. This method of treatment is the one most employed by those who devote any care to their trees; and it is here recommended as the most advisable procedure, except in cases where a skillful tree specialist is in charge.

The mistletoe plant is so brittle that it may easily be broken off, and by means of a hook attached to a long pole there is little difficulty in reaching any branches too large to be advisedly cut off. A better way, however, is to use a pruning hook attached to a pole. By this means the mistletoe may be cut off level with the bark and also many of the undeveloped buds destroyed, besides leaving the branch with a better appearance. The time and trouble, or the expense, required to keep trees free from mistletoe outgrowths in this way are really slight, compared with the advantage to be gained. A ladder of some kind, a pruning hook made by a blacksmith at the cost of perhaps a dollar, and two or three hours every year devoted to cleaning each tree will represent an average outlay. Naturally the best time to do this will be during the winter after the leaves have fallen, so that the mistletoe shoots may be more readily seen, but before the berries have become ripe enough to scatter the infection. If, however, the trees are gone over every year, or even every second year, there will probably be no question of berries on such young mistletoe shoots, and in that case the tree cleaning might better be done in the spring, when the parasite is ready to develop new shoots, thereby checking the new season's growth more effectually. This can be done before the new leaves on the host tree are large enough to conceal the mistletoe. In cases where the tree is full of mistletoe bunches the first cleaning up will naturally represent a greater outlay, for of course this will include the pruning of small infected branches, which is the most difficult and time-consuming item. In the larger towns and cities it is possible to employ experienced help in cleaning the trees of mistletoe, and this at no greater cost than that just indicated.

In some instances trees become so thoroughly infected that all the larger branches are sawed off close to the trunk, thus sacrificing the entire crown. In a dry climate like that of central Texas this is almost equivalent to sacrificing the tree permanently, for even

though new branches are put forth the violent drying out at the sawed-off end of the branch extends back to the new branches, and they are killed. In such a case there would manifestly be much help in painting the cut surface with a heavy coat of tar or asphalt paint, or some other waterproof substance. This is advised in any case where a wound is made, as in scraping with a pruning hook or in cutting off small branches. It is questionable whether wholesale lopping-off of large branches is ever advisable.

POSSIBILITY OF ELIMINATING OLD INFECTIONS.

Can mistletoe be completely eliminated from large branches or trunks without fatal injury to the host? This bulletin does not pretend to give a satisfactory, or at least a final, answer based on sufficient demonstration, but it may present a statement of the case in the hope of calling forth more activity in the way of attempts to solve the problem practically.

Under the writer's direction, branches of a 10-inch hackberry were painted or smeared with the following preparations: (1) A strong wood preservative known as "carbolineum," (2) asphalt paint, and (3) laundry soap. In each case the mistletoe was shaved off flush with the bark before the preparation was applied. Also in each case a space was treated with the preparation and left without further covering, while a similarly treated space was wrapped closely with burlap. At the end of fourteen months (July 2, 1908) the report was as follows:

(1) Where carbolineum was used no mistletoe appeared, whether the branch was wrapped or not. The preparation had not perceptibly injured the branch.

(2) Where asphalt paint was used and the treated space not wrapped, mistletoe reappeared, but not until the following season. Where the treated space was wrapped, no mistletoe appeared after the wrapping was removed, eleven months from the date of its application.

(3) Where laundry soap was used mistletoe promptly reappeared as vigorously as before it was cut back and treated. On the wrapped branch mistletoe began to sprout up as soon as the wrapping was removed at the end of eleven months.

This report would seem to indicate that a strong preservative like wood creosote or carbolineum may be applied with a brush or cloth in quantity sufficient to kill mistletoe, without seriously injuring the branch or tree. Also that milder preparations, such as asphalt paint, coal tar, and white lead, may be applied with the result of checking the development of young mistletoe shoots, and by the additional precaution of wrapping the branch the parasite may be effectually killed.

TREE SURGERY AS APPLIED TO MISTLETOE INFECTION.

Another method of treatment will have suggested itself in the case of infected limbs which are too large to be advisedly cut off and in cases where the trunk is infected. Since the repeated development of mistletoe shoots takes place from buds formed on the cortical roots and since these roots extend only in the soft bark (cortex), why not cut away the bark and cortex down to the zone of young wood at these infected places? If the infection is a recent one or if the infected area is very small this would be a simple matter of applying a gouge or chisel locally, care being taken to cut far enough from the point of attachment of the mistletoe to include the spreading cortical roots. Thus there would result a small wound from 1 to 4 inches in diameter and extending into the branch perhaps one-eighth of an inch below the inner margin of the soft bark. This should be treated with an antiseptic wash, as indicated later, and painted with asphalt paint or coal tar or lead in oil.

In the case of old infection where the cortical roots have spread widely the removal of infected tissue could be accomplished also by means of chisel and mallet, but in such cases the size of the wound becomes a serious feature. In most cases of this sort it would be better to combine the surgical method with the chemical treatment and wrapping previously described. Thus with a chisel and mallet cut out each shoot or bud or bit of exposed cortical root of the mistletoe, making no wounds larger than the diameter of the shoot or bud removed; then paint with carbolineum and wrap with burlap, or treat with an antiseptic wash and then paint with asphalt paint, coal tar, or other waterproof dressing.

In this connection a word may be said about the general subject of mutilation of trees and the treatment of wounds in trees.[a] It should be understood that every wound on a tree invites disease from some fungous or bacterial infection. Unwise or careless pruning or trimming of trees is a source of much ultimate and really preventable damage. It is of course necessary to cause these wounds, but to leave them ragged and undressed is not necessary, nor is it any more rational than it would be to treat animals by the same cruel system of surgery. Whenever a wound is made on a tree, whether in ridding it of mistletoe or from whatever cause, it should be disinfected and dressed so that no disease spores can enter while the wound is healing over. The antiseptic wash may be prepared by dissolving 1 part of corrosive sublimate in 1,000 parts of water;

[a] For further advice in this connection, see "Pruning," Farmers' Bulletin 181, by L. C. Corbett, and "Diseases of Ornamental Trees," by Haven Metcalf, in Yearbook, U. S. Dept. of Agriculture, for 1907.

or copper sulphate may be used, in which case 1 pound of the sulphate in 5 gallons of water makes a suitable wash. The protective dressing which follows this disinfectant usually consists of coal tar, but asphalt paint, white lead, grafting wax, etc., are used with good results. The edges of the wound should be left clean and smooth to facilitate the formation of wound tissue by which a tree attempts to heal over its wounds. In very dry seasons this dressing of tar or paint prevents the undue drying out which is apt to follow the cutting off of a branch. In unprotected stubs this drying out may kill the tissue several inches back of the cut end, and thus kill also the newly forming shoots, besides eventually causing a diseased spot. This precaution should especially be heeded by those who follow the practice—common in central Texas—of transplanting closely pruned trees, especially the young hackberry and cedar elm. The common custom of transplanting such trees without a ball of dirt around the roots and pruned back almost to the trunk is not advised as the best way to secure a rapidly growing, healthy shade tree; but if it is followed, surely the cut ends of the stubs should be painted to prevent drying out.

THE CARE OF TREES.

Perhaps after all is said it still remains that the most fundamental question involved in the enterprise of combating mistletoe is that of the selection and care of trees. It seems pretty obviously a case of neglect where a tree is allowed to become burdened with dozens of bunches of mistletoe until it becomes a deformed, unsightly object or completely destroyed. As a matter of fact, shade trees in well-kept grounds never do become so severely infected, or if they came into the careful owner's possession much infected their condition has been vastly improved. The trees which die of mistletoe infection are, in the majority of cases, those which stand along public highways, in unfenced or unimproved town lots, about neglected or abandoned residences, etc. They simply die of neglect.

That both the hackberry and cedar elm—the species which suffer most from mistletoe at Austin—may be kept healthy and free from mistletoe has been well demonstrated in numerous cases, but perhaps in none more strikingly than in that part of Austin which surrounds the university campus. This quarter has long been a center of harmful mistletoe infection. To the writer's personal knowledge numbers of trees have been killed outright by the pest in that vicinity. Plate I, figure 2, shows characteristically infected cedar elm trees standing opposite the west entrance to the campus. Just at the north of the campus are residence grounds bordered at front and side by a row of mixed cedar elm and hackberry trees. These trees are note-

worthy for their vigorous and symmetrical growth and also for the fact that they have made an incomparably more rapid growth than certain specimens of the same kind of trees less favorably planted on the adjacent campus. Moreover, they are and have always been practically free from mistletoe. The pest has never gained a damaging hold upon these trees. Their freedom from it and their vigorous status otherwise are due to the exercise of a reasonable amount of intelligent caretaking which began with their being well planted in the first place.

It would be a misrepresentation of public sentiment to say that there is any lack of appreciation of trees or that careful attention is not given them; but it is fairly just to say that this appreciation and care are scarcely proportional to the large measure which trees contribute to human comfort and contentment and to the long time required to bring them to the stature where they do so contribute. Viewed from this aspect, all the minute details of care and treatment implied in the foregoing suggestions become fully justified. It would be rational, furthermore, to inquire whether, in view of the great value of the individual ornamental tree, it would not be worth while to abandon the custom of grubbing up the trees and setting them out like posts in favor of the more laborious and expensive but ultimately more profitable way of lifting each tree with its ball of earth and setting it in a well-prepared place with the least possible disturbance of its roots or mutilation of its crown. Even very small saplings thus carefully transplanted will eventually outstrip the very much larger transplanted "posts".

ORGANIZED EFFORT IN THE CARE OF TREES.

The specific problem of the eradication or control of mistletoe, as well as the broader one of selection and care of shade and ornamental trees, is of the kind to be taken up by some organization devoted to civic improvement. A well-organized, well-informed, and well-directed public sentiment would speedily solve these problems. The public schools may be made active allies of the movement in behalf of the care of trees, both in receiving and in disseminating information, and in otherwise arousing an enthusiastic spirit. City and county officials may by special enactment be authorized to include in their supervision the care of trees in public parks and along streets and highways. The individual owner may be led to feel a larger responsibility for the welfare of his trees, both for the benefit they bring him and for the relation they sustain to the welfare of the community at large.

THE COMMERCIAL IMPORTANCE OF MISTLETOE.

Mistletoe is used in Christmas decorations more or less throughout this country, but especially in northern cities. Within the range of the plant it is employed more or less in this way, especially by those to whom it is still a novelty. Countless packages of it are sent through the mails and by express to friends in the North. There is, however, a well-defined Christmas trade in mistletoe by which the markets in the North are supplied. The choicer and more expensive grades are handled by southern florist supply firms. Only well-berried shrubs are used in this trade, and these are crated with great care to insure against shattering and freezing in transit. These shipments reach the retail trade through the agency of northern firms dealing in florists' supplies. Even larger quantities of mistletoe are retailed in the northern markets by grocers and market men. These supplies are handled with less care and are cheaper than florist-trade mistletoe. Some of these supplies come from southern dealers in general merchandise, who add the handling of mistletoe as a special holiday feature of their business. The mistletoe is brought in by countrymen and its value taken in trade. It is then packed in barrels or crates and shipped to northern commission houses, and by them distributed to the retail grocery and market trade.

Apparently this Christmas trade has drawn upon mistletoe supplies only in relatively few localities. So far as the general supply is concerned the market might be widely extended. Judging by the appeal which this curious plant makes to the average person it would appear to be possible to greatly multiply the purchases of it throughout the North in smaller cities and towns, as well as in the larger, to which the market seems at present to be largely limited. On the other hand, there is constant inquiry from districts in which mistletoe is abundant for information as to the possibility of finding a market for it. An increased demand for mistletoe for Christmas purposes would constitute an important factor in the control of mistletoe as a pest, but as a matter of fact it is unlikely that the plant will ever be regarded very generally in that light.

SUMMARY.

(1) In general, the American mistletoe, like its European prototype, is more cherished because of its biologic interest and historic setting than feared for its harmfulness to trees. In some districts, however, notably in central Texas, its destructiveness as a tree parasite outweighs other considerations in its behalf.

(2) The region in which mistletoe is most destructive coincides with the transition from a humid climate favorable for forest growth to a dry climate less favorable for trees, and where the effects upon tree growth are such as to furnish the parasite more favorable light

conditions than in the closer stands and denser foliage of humid climate forests.

(3) The harmfulness of mistletoe is due in part to its mechanical injury to trees (deformity of branches and trunk, wounds followed by decay), but more especially to its drain upon the trees' vitality by withdrawing water and nutriment substances from them. The sinkers which connect the parasite with the water-transporting vessels of the wood and the cortical roots which ramify in the soft bark are the means by which the parasite withdraws substances from its host.

(4) The first infection of a tree by mistletoe takes place only through the agency of a germinating seed placed upon the body or branch of the tree by birds (mostly mocking birds, wax wings or cedar birds, and robins), except in the rare case where berries fall upon a branch from a bunch of mistletoe in an overtopping adjacent tree. The subsequent spread of infection upon a tree may take place by the falling or washing of berries upon other parts of the tree from the previously established mistletoe shrubs, or by the spread of cortical roots from which new mistletoe shoots arise. Spreading by cortical roots occurs more readily upon some species of trees than upon others, and is especially stimulated by the injury or removal of the original shoot.

(5) The mistletoe seed and seedling exhibit unusual powers of resistance to drying out, and are thereby enabled to survive in considerable numbers the critical period from the time the berry is placed upon a branch until the parasitic plantlet becomes established. This period may extend beyond the first growing season.

(6) A tree may become infected at any point where living tissue is exposed or covered only by a thin layer of cork with breathing pores, but the most vulnerable points are the young branches and, sometimes, buds. The sinker of the mistletoe seedling is able to penetrate certain tissues by dissolving the walls of cells lying in its path. It is uncertain whether cutinized or corky cell walls can be so dissolved, but the writer believes that they can.

(7) The trees most liable to infection are those which occur singly or in clumps or rows along streets and highways, in vacant lots and parks, along the border of fields, and narrow strips of timber along streams. The damage to trees in forest stands is negligible. Shade and ornamental trees suffer most.

(8) While it is not certain that any broad-leaved tree is wholly immune to attack from the American mistletoe, some are practically so, although freedom from infection seems to vary with locality. In the choice of trees for planting the question of the ability of a tree to resist infection might profitably be considered. It is believed that any tree subject to infection may be infected by seed from mistletoe growing upon any other species; e. g., the hackberry may be infected

by seeds of mistletoe grown on the elm, the live oak from those on the mesquite, etc.

(9) The damage to trees may be very largely overcome by breaking and scraping off the bunches and scattered sprouts of mistletoe every year or two. If the parasite is attached to small branches these may be pruned off a few inches below the mistletoe, and thus the infection be wholly removed at that point.

(10) Infection upon old branches and upon the trunk is very difficult to get rid of, because the cortical roots spread freely in the soft bark and any piece left there may give rise to new mistletoe sprouts. Since the cortical roots do not extend into the wood (of course sinkers do), the removal of the hard and soft bark clean to the wood about an infected spot should exterminate the parasite at that point. The objection to this method is that it necessitates large wounded surfaces. Such wounds should always be disinfected and afterwards coated with tar.

(11) In some cases mistletoe has been killed from old branches by the application of chemicals, which is made more effective by subsequently wrapping the limb with burlap. Thus carbolineum alone, and asphalt paint with burlap wrapping, were found to eliminate the infection.

(12) It is suggested that a combination of the above methods would be effective. First, remove with gouge or chisel the exposed shoots or buds of mistletoe down to the wood without making large wounds; fill the larger wound holes with tar, and paint the whole surface with carbolineum or with asphalt paint. When asphalt paint is used wrap afterwards with burlap.

(13) The cutting off of large branches in order to get rid of mistletoe is to be discouraged. It is apt to injure a tree more than the mistletoe would, particularly if the latter be broken or scraped off every few years.

(14) Every wound on a tree, e. g., those caused by digging out mistletoe or by cutting off branches, is a point of attack for disease-causing germs. Such wounds should always be disinfected and painted with tar or some similar waterproof coating.

(15) The mistletoe question resolves itself largely into the question of the care of trees. The spoiling or killing of trees by mistletoe is due chiefly to neglect. A well-organized movement in behalf of civic improvement would help to remedy this defect. City and county officials who have charge of streets and parks and public highways should be required to see that trees on public ground are kept free from mistletoe.

(16) The use of the mistletoe in Christmas decorations gives it a commercial status which has some bearing on the question of its control and extermination.

DESCRIPTION OF PLATES.

PLATE I. Fig. 1.—An isolated hackberry tree near Belton, Tex., with innumerable bunches of mistletoe. This tree is in its winter condition, being absolutely without leaves of its own. Fig. 2.—A cedar elm tree on a vacant lot in Austin, Tex., showing its winter condition. All the foliage is mistletoe.

PLATE II. Fig. 1.—A water oak tree in a creek-bottom field near Bryan, Tex. Numerous bunches of mistletoe 2 or 3 feet in diameter are shown at the ends of the slender branches. Fig. 2.—A deformed branch of a hackberry tree which has been infected by mistletoe for ten or twelve years. The dwarfing of the branch beyond the place of infection is shown. The original mistletoe plant has been destroyed, leaving a decayed spot. Young shoots of mistletoe from adventitious buds.

FIG. 1.—AN ISOLATED HACKBERRY TREE NEAR BELTON, TEX., WITH INNUMERABLE BUNCHES OF MISTLETOE.

This tree is in its winter condition, being absolutely without leaves of its own.

FIG. 2.—A CEDAR ELM TREE ON A VACANT LOT IN AUSTIN, TEX., SHOWING ITS WINTER CONDITION.

All the foliage is mistletoe.

FIG. 1.—A WATER OAK TREE IN A CREEK-BOTTOM FIELD NEAR BRYAN, TEX.

Numerous bunches of mistletoe, 2 to 3 feet in diameter, are shown at the ends of the slender branches.

FIG. 2.—A DEFORMED BRANCH OF A HACKBERRY TREE WHICH HAS BEEN INFECTED BY MISTLETOE FOR TEN TO TWELVE YEARS.

The dwarfing of the branch beyond the place of infection is shown. The original mistletoe plant has been destroyed, leaving a decayed spot. The young shoots of mistletoe seen are from adventitious buds.

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